International Journal of Environment, Ecology, Family and Urban Studies (IJEEFUS)
ISSN (P): 2250–0065; ISSN (E): 2321–0109
Vol. 11, Issue 2, Dec 2021, 87–96

ENVIRONMENTAL SENSITIVITY INDEX EVALUATION OF OIL SPILL FOR ENVIRONMENTAL MANAGEMENT: A CASE STUDY OF UKPIOVWIN UDU LOCAL GOVERNMENT AREA, DELTA STATE, NIGERIA

NWOKORO CHIJIOKE[1] & ONOSEMUODE CHRISTOPHER[2]

[1]*Department of Environmental Technology and Management, Faculty of Management, Lincoln University College Malaysia*

[2]*Department of Environmental Management and Toxicology, College of Science, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria*

ABSTRACT

The study focused on environmental sensitivity index evaluation for environmental cleanup in an oil polluted ecosystem. The emphasis is on the use of Geoinformatic techniques to create an Environmental Sensitivity Index (ESI) map of the polluted ecosystem to assess the level of vulnerability of resources that were at risk in the area covered by the oil spill. An Ikonos imagery of 2018 of the study area was acquired, a landuse/cover classification scheme comprising of built up area, wetland, natural vegetation, farmland, bare land and water bodies was adopted. Categorization, ranking and classification of the inland habitat was carried out, while the buffer zones of 100m, 200m, 300m and 400m was used. In an ArcGis 10.5 environment, the landuse/cover map was generated. Buffer distances of 100m, 200m, 300m and 400m were created on the landuse/cover map to ascertain the features that were vulnerable at different buffer zonesl. The study concluded that the built up areas were the most sensitive feature along the created buffer zones followed by water bodies, natural vegetation and farmland which have strong ties with inhabitants. An Emergency Response Zone (ERZ) was established at Ugbisi community within 50m buffer zone.

KEYWORDS: Oil Spill, Vulnerability, Cleanup, Buffer Zone & Management

Received: Jul 18, 2021; **Accepted**: Aug 08, 2021; **Published**: Sep 03, 2021; **Paper Id.**: IJEEFUSDEC202111

Original Article

INTRODUCTION

Oil undoubtedly is one of the influential commodities in the world market today. It is also a highly priced product of the extractive industry. In 1956, Royal Dutch Shell discovered crude oil at Oloibiri, a village in the Niger Delta, and commercial production began in 1958 (Nwilo *et al.*, 2006). Since then, Nigeria's economy is heavily dependent on earnings from the oil sector, which provides 78% of GDP, 90% of foreign exchange earnings and budgetary revenues (CIA World Fact Book, 2005).The importance, uses and overall benefits of petroleum (crude oil) otherwise known as rock oil cannot be overemphasized. From factories, machineries and transportation to electricity generation, crude oil has become a major source of energy that affects all sectors of any nation and its economy. But as important as this natural resource may be, the process involved in its exploration, extraction and transportation most often impinge on the environment (Aroh *et al.*, 2010). It is indeed extremely difficult to separate oil spill incidents from oil exploration and exploitation (Aroh *et al.*, 2010, Onosemuode et al., 2019). Thus, the oil-bearing communities and their environs has been suffering the negative environmental consequences in term of oil spillage on land and water bodies especially the coastal area of the Niger Delta which is the home to oil

explorations and exploitations in Nigeria. The total spillage of petroleum into the oceans, seas and rivers through human activities is estimated to range 0.7-1.7 million tons per year. Oil spills have posed a major threat to the environment of the oil producing areas, which if not effectively checked can lead to the total destruction of ecosystems (Kadafa *et al*., 2012). In Nigeria, fifty percent (50%) of oil spills is due to corrosion, twenty eight percent (28%) to sabotage and twenty one percent (21%) to oil production operations. One percent (1%) of oil spills is due to engineering drills, inability to effectively control oil wells, failure of machines, and inadequate care in loading and unloading oil vessels (Adati, 2012).

In the Niger Delta, huge oil exploration and production are associated with frequent and rampant crude oil spills.

Spillages of this product on the coastal environment could be sometimes very disastrous, depending on the volume of the oil spilled which could have internal and external effect on plants, animals and socioeconomic effects like the fishing industry, resorts and recreation areas, water supplies for drinking and industry amongst others. Spilled oil is able to impair living things since its chemical constituents are poisonous (Tanzadeh and Ghasemi, 2016; Alencar and de Almeida, 2010; Lins and de Almeida, 2012). The impacts of the oil spillages in the Niger Delta are numerous; such as adverse effect on the growth of plants due to widespread contamination of soil, pollution of water bodies (Oyem and Isama, 2013; William, and Benson, (2010), impingement on organisms through internal exposure (ingestion and inhalation) and external exposure (skin and eye irritation) that causes infertility and cancer (Tanzadeh and Ghasemi, 2016). Despite global awareness of oil spill incidents, little attention is paid to onshore oil spills compared to offshore (Reible, 2010; Chen and Denison, 2011). In managing an instance of oil spill, the study area which is located between Latitudes 5˚ 26ˈ 0" N - 5˚ 27ˈ 30" N and Longitudes 5˚ 49ˈ 30" E - 5˚ 52ˈ 0" E within Delta state of Nigeria focuses on environmental sensitivity index (ESI) evaluation for the prioritization and management of oil spill cleanup.

METHODS

Data Types and Characteristic

The various landuse/cover and the buffer zones, were generated from an Ikonos imagery of 2m resolution using ArcGIS 10.5 software.

Inland Habitat Classification

Based on fieldwork data collected coupled with images downloaded from Google Earth with geo-referencing on ArcGIS 10.5, a classification pattern was developed to enhance the classification of the land-use and land-cover inland habitat in the study area. The system of classification is shown in table 2.

Table 2: Land uses/Cover Classification System

S/N	Landuse/cover Class
1	Built up areas
2	Wetland
3	Natural vegetation
4	Farmland
5	Bare land
6	Water bodies

Categorization, Ranking and Classification of the Inland Habitat

The main criteria considered to establish the degree of sensitivity to oil spill and other stress factor of an ecological class

include its biological productivity, oil/ecology interaction and ease of clean up, and social, economic and human importance as posited by Fasona et al., 2011 was adopted in this study and shown in table 3.

Table 3: Land use/Cover Sensitivity Ranking and Classification

Landuse/cover	Environmental Sensitivity Index (ESI) Rank	ESI Class
Built up area	VH	5A
Water bodies	VH	5B
Natural vegetation	VH	5C
Farmland	H	4D
Bare land	L	1F

Creation of Buffer Zones

The buffering operation helps in knowing the proximity of resources that are vulnerable or sensitive to oil spill. It is also to assess the hazard areas along the oil pipeline as it affects the land-use and the land-cover. Buffer distances of 50m, 100m, 200m, 300m and 400m (Table 3) were adopted as used by Michael *et al*., (2017), Santos GLNG (2009), and Chevron (2015).

Emergency Response Zone

Emergency response zone is a location strategically positioned at area considered to be easily accessible; between area where the inland habitat features are likely to suffer great harm and where responders and equipment can easily be deployed within a short time after oil spill incident has been reported. The proposed emergency response zone along the study area is chosen by considering the following factors (a) the most delicate inland habitat feature and (b) the proximity and accessibility of required responders and equipment deployment along the pipeline route (Onosemuode *et al*., 2019).

RESULTS AND DISCUSSIONS

The results of the image processing, ecological classification of the inland habitat and its ESI ranking and the use of buffer standards of 50m, 100m, 200m and 400m respectively for the establishment of the various habitat classes are presented. The buffered zones enhance the determination and quantification of the proximity in terms of the area covered by each classified landuse/cover as shown in Table 4.

The Environmental sensitivity index (ESI) map of the study area which covers 5.7km of the pipeline passing through Ugbisi, Ukpiovwi and Otujeremi communities and environs in the study area (Figure. 1), provides a concise summary of the resources that could be at risk in the event of spillage within the buffered zones of 50m, 100m, 200m and 400m respectively in the study area. While **table 5** shows the ranking and the classification of the landuse/cover of the study area.

Table 4: Statistics of the Land use/Cover for the Different Buffer Standards

Buffer Standards	Buffer 50m		Buffer 100m		Buffer 200m		Buffer 400m	
LULC class	**Area (ha)**	**100%**	**Area (ha)**	**100%**	**Area (ha)**	**100%**	**Area (ha)**	**100%**
Bare Surfaces	4.1874	7.33	5.7790	5.78	11.0796	4.86	19.8731	4.36
Built Up Areas	12.2957	21.53	23.1693	23.17	62.0101	27.17	134.9439	29.57
Farmland	0.3085	0.54	0.9740	0.97	2.8049	1.23	5.3140	1.16
Natural Vegetation	37.8851	66.33	68.3648	68.36	151.4708	66.38	286.3710	62.76
Water Body	0	0	0.0530	0.05	0.6176	0.27	5.3245	1.17
Wetland	4.0287	7.05	5.2589	5.26	10.8485	4.75	29.2994	6.42
Total	**57.1177**	**100**	**100**	**100**	**228.1932**	**100**	**456.3218**	**100**

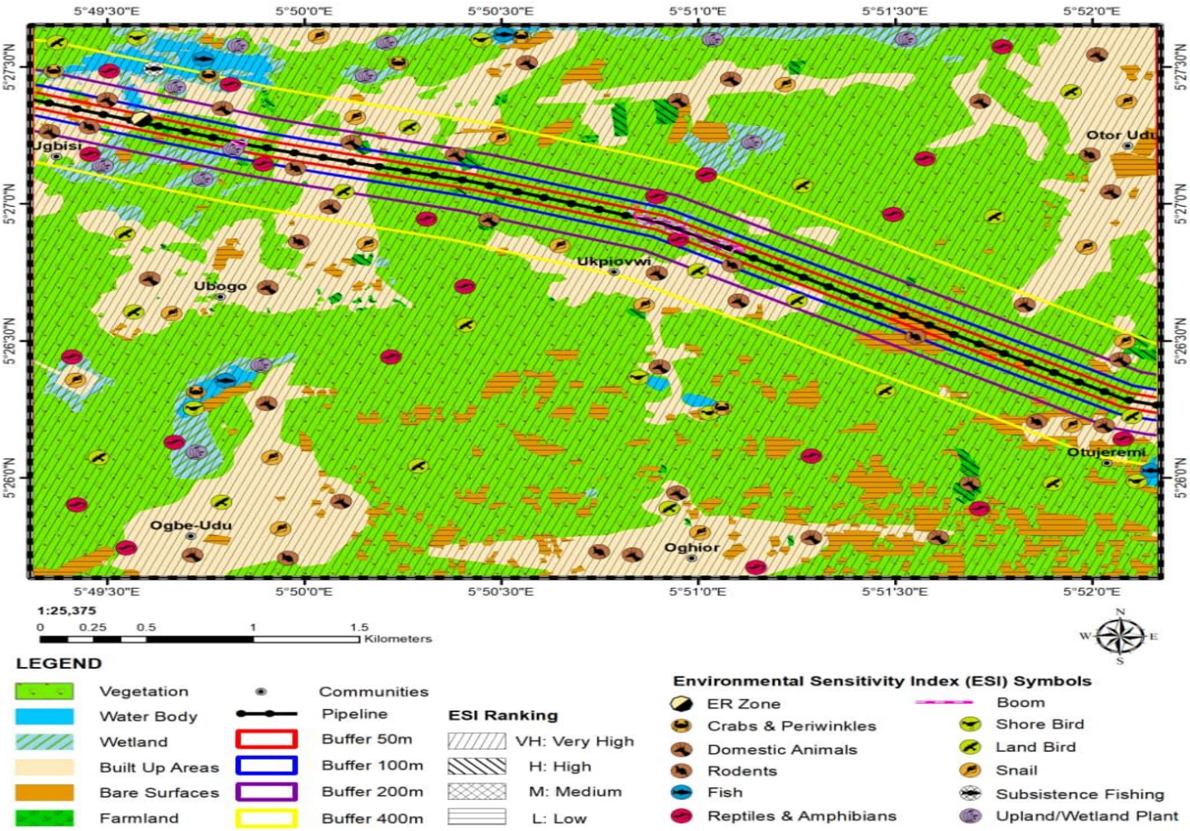

Figure 1: Showing ESI Map of the Study Area.

Table 5: Landuse/Cover Sensitivity Ranking and Classification

Landuse/cover Classes	Environmental Sensitivity Index (ESI) Ranks	ESI Class
Built up area	VH	5A
Water bodies	VH	5B
Natural vegetation	VH	5C
Farmland	H	4D
Wetland	H	4E
Bare land	L	1F

Sensitivity Index Ranking and Classification of the Landuse/Cover in the Study Area

The various landuse/cover identified in the study and their ranking and classification are discussed below.

Natural Vegetation ESI Classification and Ranking for the Buffer Zones

The natural vegetation is the feature that occupies the most and largest area of land use/cover in the map within the buffer zones. It comprises of grassland, shrubs, and mangrove forest and faunas species like rodent, squirrel and grass-cutter, chameleon, snakes etc. Natural vegetation occupies a total land area of 37.8851 hectares (66.33%), 68.3648 hectares (68.36%), 151.4708 hectares (66.38%), and 286.3710 hectares (62.76%) within the 50m, 100m, 200m and 400m (Table 4) buffer zones respectively.

The natural vegetation comprises mainly of grassland, mangrove forest and shrubs (scrub) in the areas. The grassland, mangrove forest and shrubs are ranked as Very High (VH) with ESI class of 5C (Table 5 and Figure. 2) due to its proximity to the pipeline, human settlement and built up areas. This cognates that natural vegetated habitats are considered to have medium to high sensitivity to oil spills and it's in line with the study of Onosemuode et al., (2019). The biological diversity in this habitat is significant because they provide critical habitat for many types of animals and plants. Oil spills can affect both the natural vegetation and the organisms that rely on them causing the soil micro fauna, creeping and crawling species to suffer mortality or extinction when exposed to the harsh condition of oil spill.

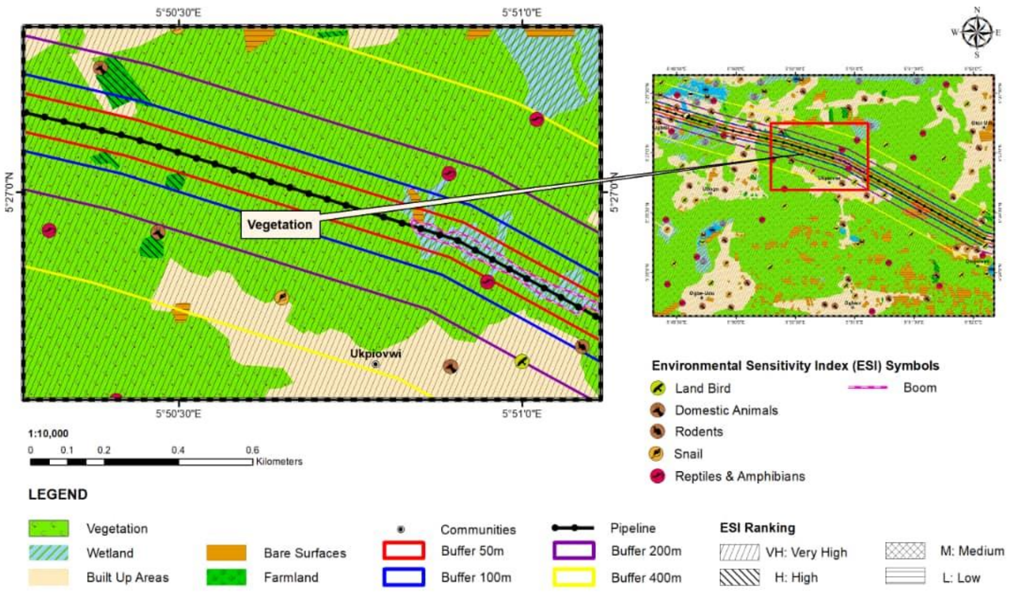

Figure 2: ESI Map of Natural Vegetation within the Buffer Zones.

Built Up Area Component of the ESI Map within the Buffer Zones

The built up areas comprises mainly of residential, utility, commercial, religious and educational structures. The settlements within the buffer zones are Ugbisi, Ubogo, Ukpiovwin, Otujeremi and suburb communities with other sparsely distributed hamlets. This area comprises of diverse floras like mango trees, coconut and palm trees, pawpaw, sunflower, water leaf, bitter leaf, scent leaf plants and shrubs while some portion of built up area are covered fields and gardens. The faunas consist mainly of domestic animals such as dog, goat, fowls, rat, wall gecko, lizard, frog, cats, insects and microbes that may not visible. The built up area occupies a total land area of 12.2957 hectares (21.53%), 23.1693 hectares (23.17%), 62.0101 hectares (27.17%), and 134.9439 hectares (29.57%) (Table 4.2) within the 50m, 100m, 200m and 400m buffer zones respectively. This means that in the event of any spillage the built up area would mostly be at risk within the 50m

buffer due to the presence of socio-economic and other activities that may have direct relationship with the people and the impact decreases as the buffer distances increases to 100m, 200m and 400m. The built up area has a Very High (VH) sensitivity index ranking of 5A (Table 5 and Fig. 3). This entails that this habitat is ranked the most sensitive of all the inland LULC features around the pipeline because of the potential impact of the spillage on human health and socioeconomic activities in such area.

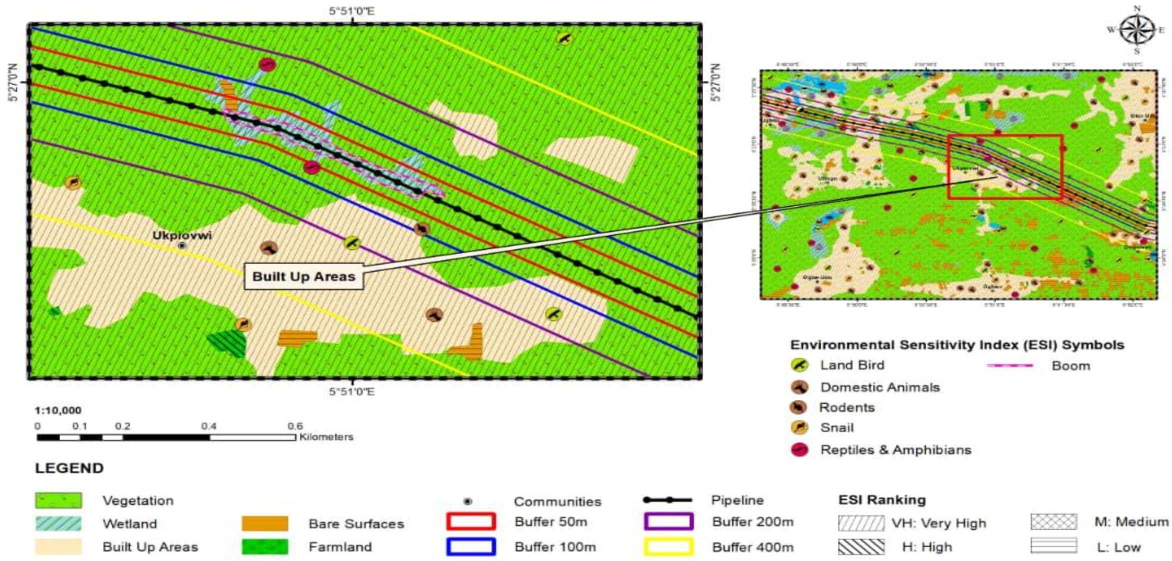

Figure 3: ESI Map of Built Up Area within the Buffer Zones.

Water Body Component of the ESI Map within the Buffer Zones

The water body within the buffer zones comprise of rivers, streams, ponds and creeks. The water body serves as a source of drinking water, bathing water and for other domestic purposes for some masses in the rural settlements around the study area. It also serves as habitat to aquatic plants and animals of various diversities like water lilies, water hyacinths, frog, toads, shrimps, crabs, periwinkle, turtles, fishes, and some reptiles. There is no water body within the 50m buffer zone (Figure. 4). It is also recorded that water bodies occupy a total land area of 0.0530 hectares (0.05%), 0.6176 hectares (0.27%), and 5.3245 hectares (1.17%) within the 100m, 200m and 400m buffer zones respectively (Table 4). The water body has Very High (VH) ESI ranking of 5B (Table 5). This entails that this habitat is highly sensitive to oil spillage because different kinds of mammals, birds, reptiles, and amphibians use the stream bank as habitat, and there can be localized high mortality rates of these animals in times of oil spillage. Oil spills may have more impact on water bodies in the zoned area due to a variety of conditions, such as; lower flow condition of the water body leading to lower dilution rates, high biological and human use, and greater range of natural habitats.

.

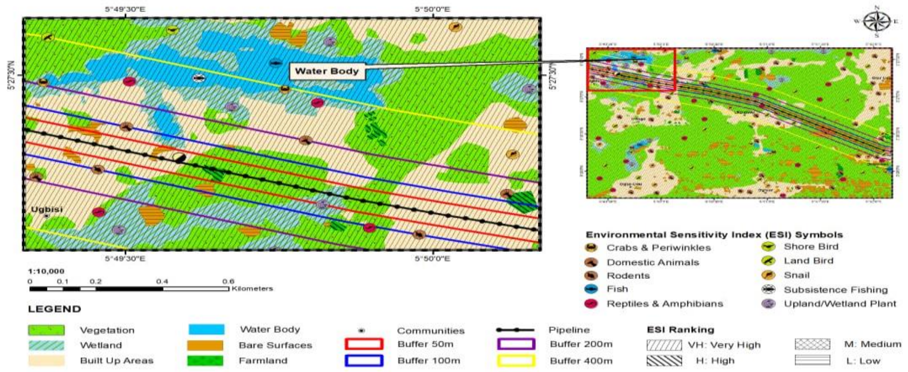

Figure 4: ESI Map of Water Body within the Buffer Zones.

Farmland Component of the ESI Map within the Buffer Zones

Farmlands are areas where agricultural activities are carried out with the aim of producing different crops for personal consumption and as a source of income. The common crops farmed within the buffered zones are plantain, cassava, yam, vegetables, potatoes to mention but few on a continuous cropping and shifting cultivation bases. The farmland area occupies a total land area of 0.3085 hectares (0.54%), 0.9740 hectares (0.97%), 2.8049 hectares (1.23%), and 5.3140 hectares (1.16%) (Table 4) within the 50m, 100m, 200m and 400m (Figure. 5) buffer zones respectively. The farmland has a High (H) ESI ranking of 4D and Moderately High (MH) ranking of 3D (Table 5). This is an indication that the farmland habitats are considered to have medium to high sensitivity to oil spills, which may result to loss of farm lands.

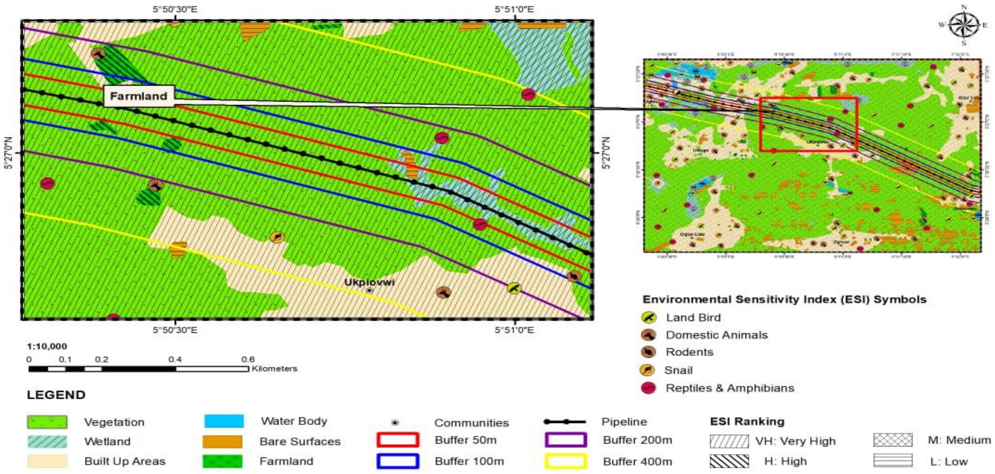

Figure 5: ESI Map of Farmland within the Buffer Zones.

Wetland Component of the ESI Map within the Buffer Zones

Wetlands are characterized by water, unique soils that differ from adjacent upland areas, and vegetation adapted to wet conditions. The wetland areas comprise of sedge, bogs, marshes/swamps, forested freshwater, wet grassland and swamps which are always dominant at the river banks. Wetland has a very rich unique biodiversity of flora and fauna species. Wetlands support populations of fish, amphibians, reptiles, birds, and mammals, with many species reliant upon wetlands for their reproduction and early life stages when they are most sensitive to oil. Migratory water-birds depend heavily on

wetlands as is the case in the study area. The wetland area occupies a total land area of 4.0287 hectares (7.05%), 5.2589 hectares (5.26%), 10.8485 hectares (4.75%), and 29.2994 hectares (6.42%) (Table 4) within the 50m, 100m, 200m and 400m (Figure 6) buffer zones respectively. The wetland has High (H) ESI ranking of 4E (Table 5). In an event of oil spill in this habitat, the chemical components of the products will persists for long, percolate and seeps into the soil which can result in the contamination of the ground water aquifer.

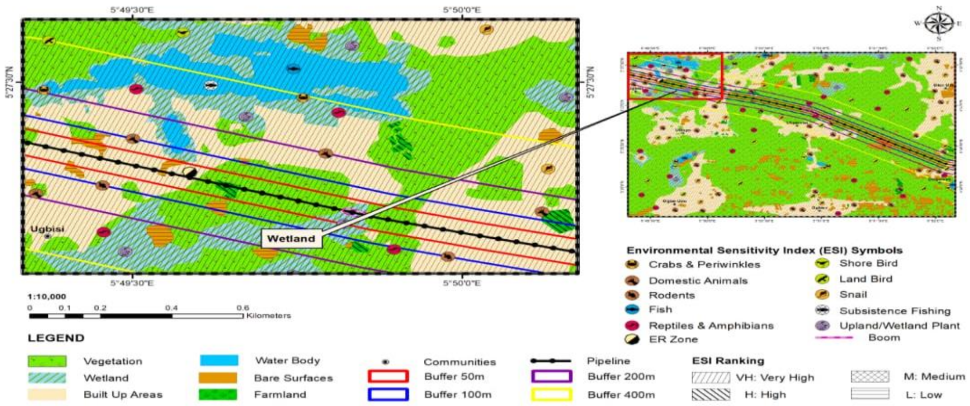

Figure 6: ESI Map of Wetland Area within the Buffered Zones.

Bare Surface Component of the ESI Map within the Buffer Zones

Bare surfaces are exposed surfaces which can be attributed to natural processes or human activities. It hardly supports plants growth because of the limited nutrients in it. The bare surfaces occupy a total land area of 4.1874 hectares (7.33%), 5.7790 hectares (5.78%), 11.0796 hectares (4.86%), and 19.8731 hectares (4.36%) (Table 4) within the 50m, 100m, 200m and 400m (Figure. 7) buffer zones respectively. The bare surface has a Low (L) ESI ranking of 1F. This explains while bare surface is least sensitive in an event of any spillage and will suffer the least impact in the buffered zones around the NGC pipeline.

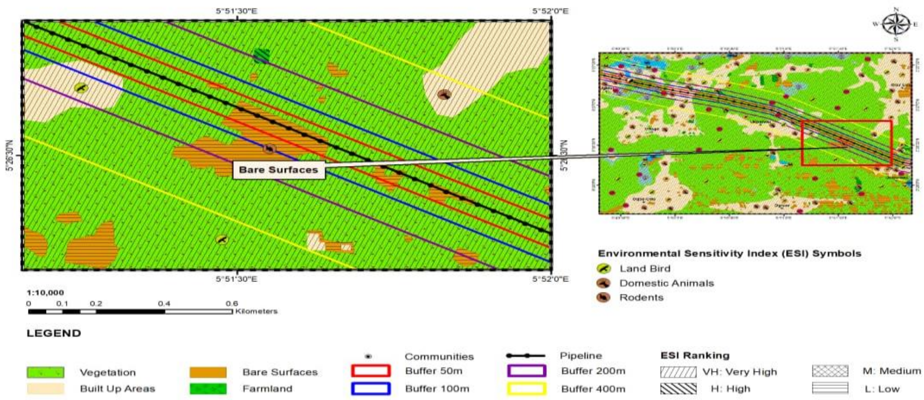

Figure 7: ESI Map of Bare Surface Area within the Buffered Zones.

The Proposed Emergency Response Zone (ERZ)

The Emergency Response Zone (ERZ) is usually strategically positioned location considered to be easily accessible; between area where the inland habitat features are likely to suffer great harm and where responders and equipment such as

hard booms, skimmers, storages, fire extinguishers and vehicles can easily be deployed within a short time after oil spill incident has been reported (Onosemuode *et al*., 2019). The emergency response zone (ERZ) has been proposed to be situated at Ugbisi community within 50m buffer zone (Figure. 8) north due to the large expanse of built up areas with high human population couple with water bodies and wetlands that are at proximity to the pipeline which may be at risk in an event of any incident of oil spill along the pipeline. Also, the proposed ER zone can easily be accessible by response team with ease of deployment of response equipment in case of potential incident of spill along the pipeline.

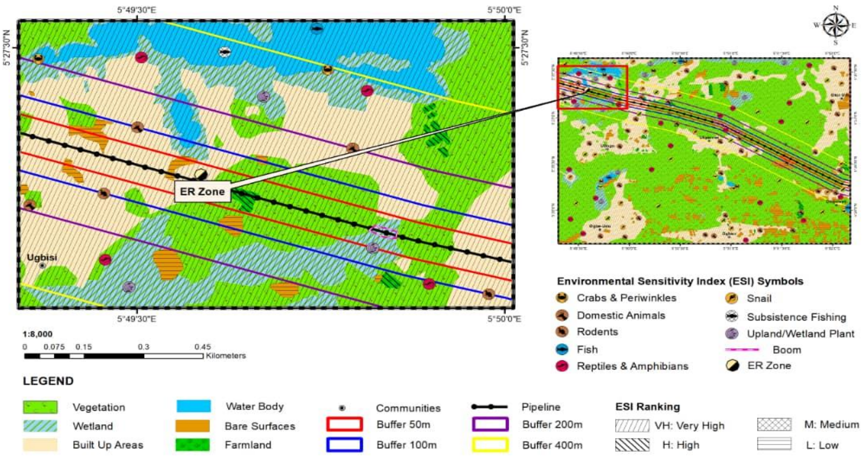

Figure 8: The Proposed Emergency Response Zone along the Pipeline.

CONCLUSIONS

The study has shown that the built up areas are the most sensitive feature along the created buffer zones followed by water bodies, natural vegetation and farmland which have strong ties with inhabitants. Hence, to reduce the potential impacts of spillages of petroleum product from the pipeline on the environment, some protective measures need to be put in place like strict monitoring of the pipeline, land use planning, policy development on emergency response management and pipeline maintenance with integrity checks.

REFERENCES

1. *Adati Ayuba Kadafa (2012). Oil Exploration and Spillage in the Niger Delta of Nigeria‖. Civil and Environmental Research, ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online) Vol 2, No.3, 2012.*

2. *Alencar, M.H. & de Almeida, A.T. (2010). Assigning priorities to actions in a pipeline transporting hydrogen based on a multi-criteria decision model. International Journal of Hydrogen Energy, Issue 35, pp. 3610-3619.*

3. *Aroh KN, Ubong IU, Eze CL, et al. (2010) Oil spill incidents and pipeline vandalization in Nigeria Impact on public health and negation to attainment of Millennium development goal: : the Ishiagu example", Disaster Prevention and Management: An International Journal, Vol. 19 Issue: 1, pp.70-87.*

4. *Chen, J. & Denison, M.S. (2011). The Deepwater Horizon Oil Spill: Environmental Fate Of The Oil And The Toxicological Effects On Marine Organization. The Journal Of Young Investigators, 21(6), pp. 84-95.*

5. *Chevron (2015). Gorgon Gas Development and Jansz Feed Gas Pipeline. Coastal and Marine Baseline State and Environmental Impact Report: Domestic Gas Pipeline, pp. 64.CIA (2005): The World Fact Book – Nigeria.htm. Assessed on the 15th of February, 2020*

6. Fasona, M. J., Soneye, A. S. O., Nwokedi, M & Oladeinde, M. (2011): Baseline Ecosystems and Sensitivity of the lowland areas of Forcados River, Western Niger Delta Nigeria, to Oil Spills" Lagos Journal of GIS 1(1), 49 – 62, June.

7. Kadafa, A. A. (2012). Oil exploration and spillage in the Niger Delta of Nigeria. Civil and Environmental Research, 2(3), 38-51.

8. Lins, P.H.C. & de Almeida, A.T. (2012). Multidimensional risk analysis of hydrogen pipelines. International Journal of Hydrogen Energy, Issue 37, pp. 13545-13554.

9. Michael, A. O., Isaac, O. O., & Benjamin, L. O. (2017). Pipeline right-of-way encroachment in Arepo, Nigeria. The Journal of Transport and Land Use. Vol. 10 NO. 1 [2017] pp. 715–724.

10. Nwilo, P.C., & Badejo, O.T. (2006). Impacts and Management of Oil Spill Pollution along the Nigerian Coastal Areas. In M. Sutherlands, and S. Nichols (Eds.), Administrating Marine Spaces: International Issues. A Publication of the international Federation of Surveyors (FIG) ISBN 87-90907-55-8.

11. Onosemuode, C., Okhae, S. E. & Okeowo, G. (2019). Environmental sensitivity index mapping: A case study of PPMC pipeline along Ugbomro Community and environ, Delta State, Nigeria. International Journal of Advanced Remote Sensing and GIS. 8(1): 2878-2888.

12. Oyem & Isama, L. R. (2013). Effect of Crude Oil on Soil Physio-Chemical Properties in Ugborodo Community, Delta State, Nigeria. International Journal of Modern Engineering Research (IJMER). Vol. 3, pp. 3336-3342.

13. Reible, D. (2010). After the oil is no longer leaking. Environmental Science and Technology, Issue 44, pp. 5685-5686.

14. Santos GLNG Project (2009). Environmental Impact Statement: Gas Transmission Pipeline Environmental Values and Management of Impacts, section 7.

15. Tanzadeh, J. & Ghasemi, M. F. (2016). The Use of Microorganisms in Bioremediation of Oil Spill in Sea Waters and Shoreline. Research Journal of Chemical and Environmental Sciences. Vol.4 [5]: 71-77.

16. William, A.B. & Benson, N.U. (2010). Inter-seasonal Hydrological Characteristics and Variability in Surface Water of Tropical Estuarine Ecosystems within Niger Delta. Journal of Environmental Monitoring and Assessment, 165(1-4), pp. 399-406.

17. Nyssanbayeva, G. R., et al. "Synthesis of modified nanocarbon materials and determination of their adsorption capacity." International Journal of Mechanical and Production Engineering Research and Development 10.1 (2020): 305-314.

18. Senthiil, P. V., V. A. Sirusshti, and T. Sathish. "Artificial Intelligence Based Green Manufacturability quantification of a unit production process." International Journal of Mechanical and Production Engineering Research and Development 9.2 (2019): 841-852.

19. Varma, Aakash, and Kamlesh Singh. "How Does Heat or Frying Process Affect Deterioration of Various Edible Oils in Indian Cooking Conditions and How the Composition of Oils Lead to Peroxide Formation?." Intl. J. Appl. Phys. Bio-Chem. Res 7.5 (2017): 13-30.

20. Elashkar, Magdy Ali. "The use of simulation techniques in the development of non-technical skills for marine officers." International Journal of General Engineering and Technology (IJGET) 5.5 (2016): 19-26.